7. Enhancing the Clarity of Low Level Decisions on the Goals of Large Complex Projects

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Abstract

The aim of the work is to examine the possibility of developing a tool to track, monitor and predict large complex system development by enhancing the clarity of how decisions at lower levels impact on the goals of the project. The approach uses Maritime Operations Division's (MOD) established ability in combat system performance modelling using MBSE and attempts to connect that level to Operational Capabilities and hence Strategy.

The paper leverages off MBSE tool capabilities, developments such as the Whole of System Architecture Framework (WSAF) and research approaches such as the Aligned Process Model (APM). The large complex project examined in this experiment is the Future Submarine project due to the authors' experience with the project, however any other large complex project would have been equally viable for the experiment.

Presenter Biography

Robert Dow graduated from James Cook University of North Queensland with Bachelor of Engineering and Master of Engineering Science Degrees in 1974. His professional engineering and scientific research career includes designing Army man-pack radios at Army Design Establishment, Maribyrnong, Victoria (1974-77); scientific instrumentation and CNC machines (1977-84) in the Engineering Division of Materials Research Laboratory (MRL); then research into sea mine target detection logic in Explosives Division of MRL (1984-1989). From the early 1990's within Maritime Operations Division he looked after a team supporting the Mine Warfare Systems Centre Project, RAN Mine Warfare Exercises and research into artificial neural networks for ordnance. He moved to MOD, DSTO-E, Adelaide in 1998 where he has worked on MBSE in support of combat systems for surface combatants and submarines. Robert Dow currently works on MBSE for Combat Systems within the Submarine Combat System Group of the Submarine Systems Branch, Maritime Operations Division, DSTO-E.

Lyn Dow has Higher Technician's Certificates from Footscray Institute of Technology in mechanical and electrical engineering. She worked in Dimensional Metrology in Materials Research Laboratory (MRL) (1970-1972), Electrical Metrology (1972-1974, 1976-1978), Camouflage (1974-1976), and Electronics (1978-1983). Returning to work in 1989, Lyn provided LAN network, computer and executive support in Maritime Operations Division. She moved to MOD, DSTO-E, Adelaide in 1998 where she has worked on MBSE in support of combat systems for surface combatants. Lyn Dow currently works on MBSE for Maritime Warfare Operations Group of the Surface Ship Operations Branch, Maritime Operations Division, DSTO-E.

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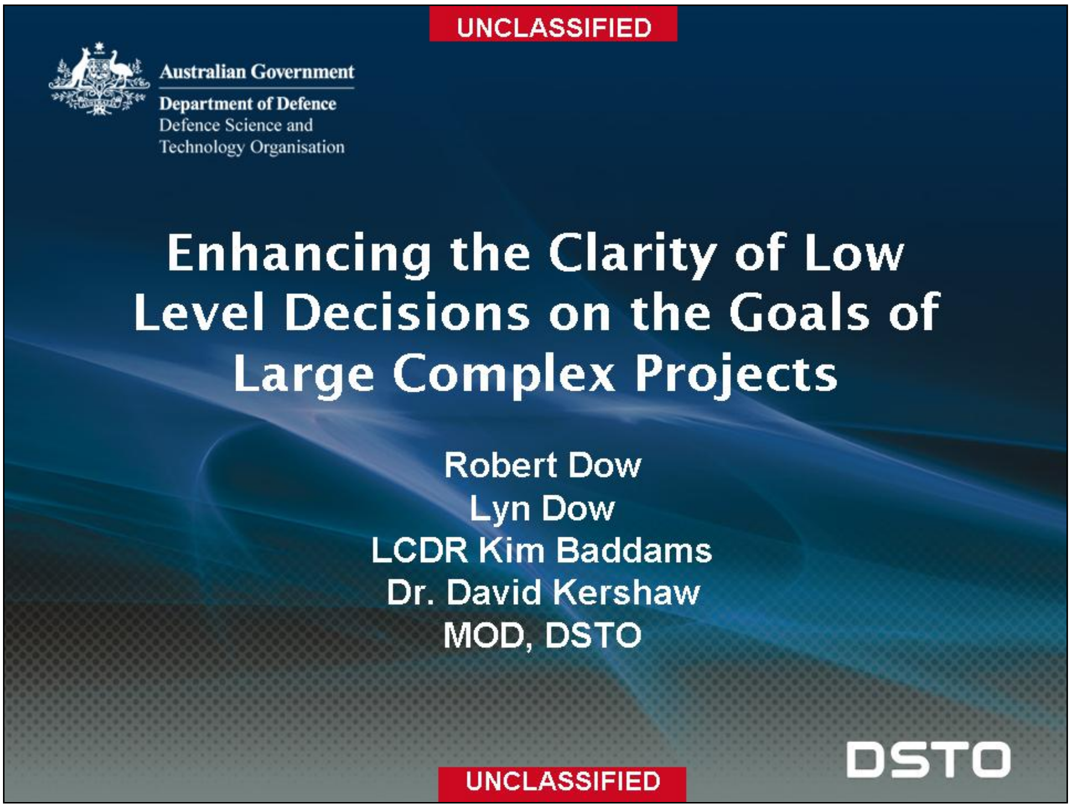
Kim Baddams served in the Royal Australian Navy from 1973 to 1998, qualifying as a fighter pilot, Air Warfare Instructor, and Principal Warfare Officer specialising in anti-submarine warfare. He held staff positions in the Naval Warfare Branch of Navy Office, where he was the inaugural Director Above and Underwater Warfare, and in the Maritime Development branch of Defence Capability Development. Since leaving full time service he has worked as a Naval Reserve in support of Navy tasks at the Defence Science and Technology Organisation, including considerable involvement with Model Based System Engineering. His qualifications include a Diploma of Maritime Studies and a Graduate Diploma of Applied Science.

David Kershaw started in Defence as a Cadet Engineer with Navy Material in 1987 and transferred to DSTO in 1989. He holds a B.Sc(Hons) in Physics, a B.E in Electrical and Computer Systems Engineering and a PhD in Tracking Systems. Positions held within DSTO have included Head of Torpedoes & Torpedo Defence Group (1999 through to 2002), Navy Scientific Adviser (2003-04), Air Warfare Destroyer S&T Adviser (2005-06), Acting Research Leader in Surface Ship Operations (Sept 2006-March 07), Head Torpedo Systems Group (2007-2010), and Head Submarine Combat Systems Group (2010-2012). David was appointed as the Research Leader Submarine Systems and SEA 1000 (Future Submarine) S&T Adviser in early 2012.

Presentation



The Challenge

To support the Decision Maker, we want to look at the possibility of **developing a tool to monitor large complex system development** by enhancing the **clarity of how decisions at lower levels** impact on the **goals of the project**.

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The V-model of the Systems Engineering Process

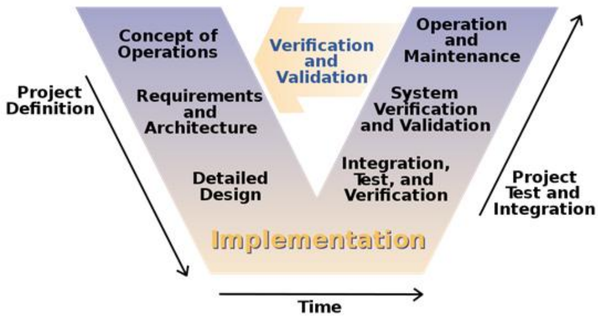

Image extracted from Clarus Concept of Operations. Publication No. FHWA-JPO-05-072, Federal Highway Administration (FHWA), 2005

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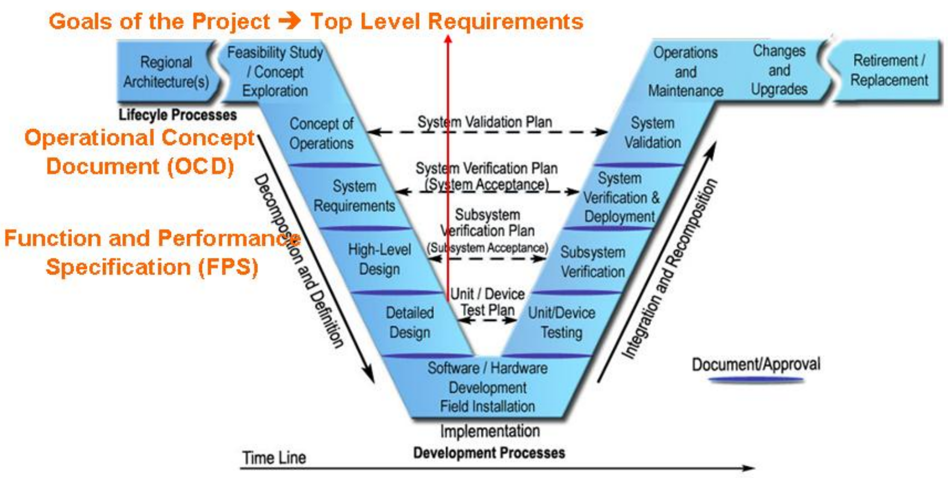
STANDARD SYSTEM ENGINEERING 'V' DIAGRAM



Section 3, Systems Engineering for Intelligent Transportation Systems, US Dept of Transportation, 2007

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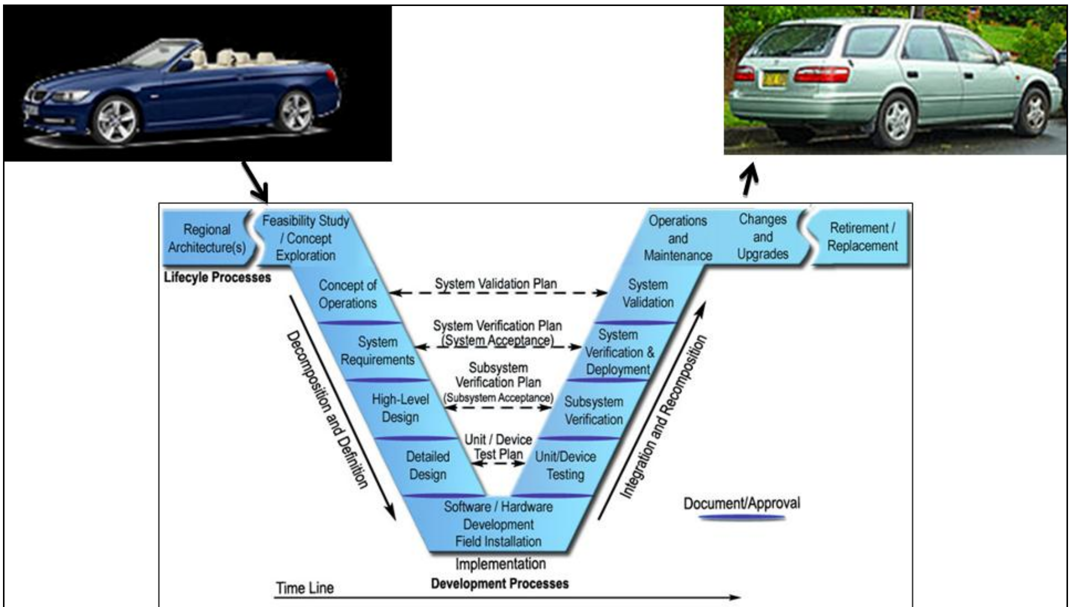

Section 3, Systems Engineering for Intelligent Transportation Systems, US Dept of Transportation, 2007

When did this happen? Was this a conscious decision?

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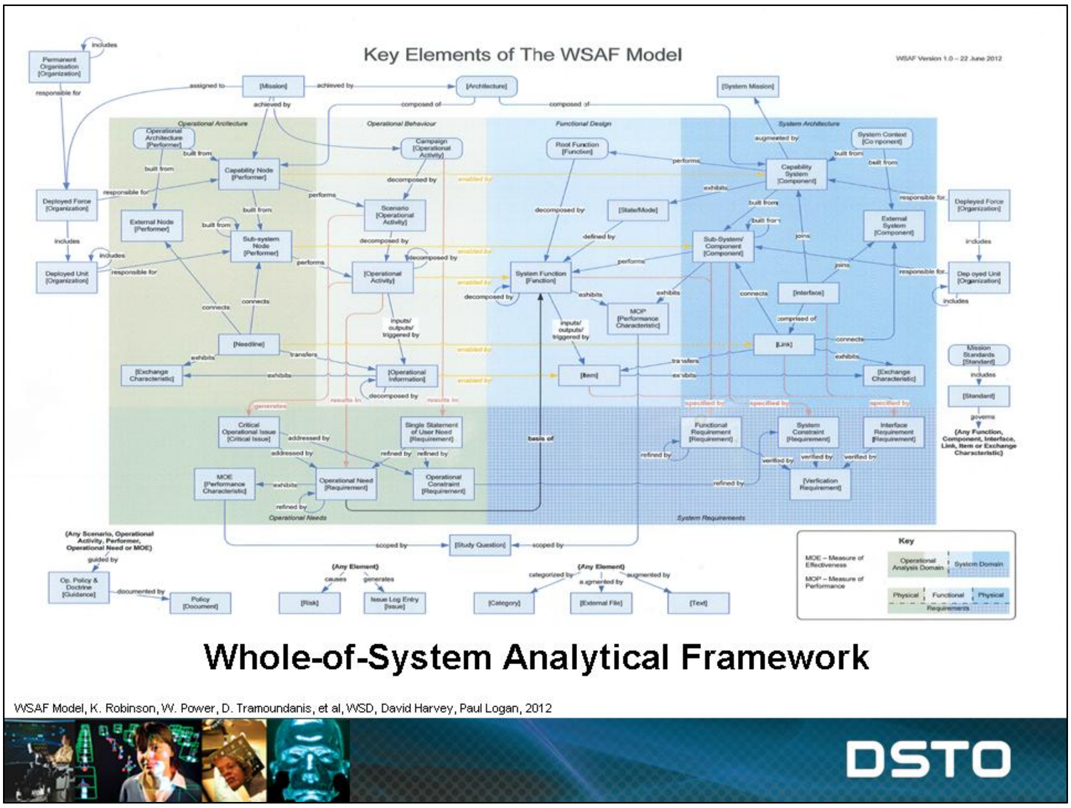
Key Elements of The WSAF Model
WSAF Version 1.0 – 22 June 2012
Whole-of-System Analytical Framework
WSAF Model, K. Robinson, W. Power, D. Tramoundanis, et al, WSD, David Harvey, Paul Logan, 2012
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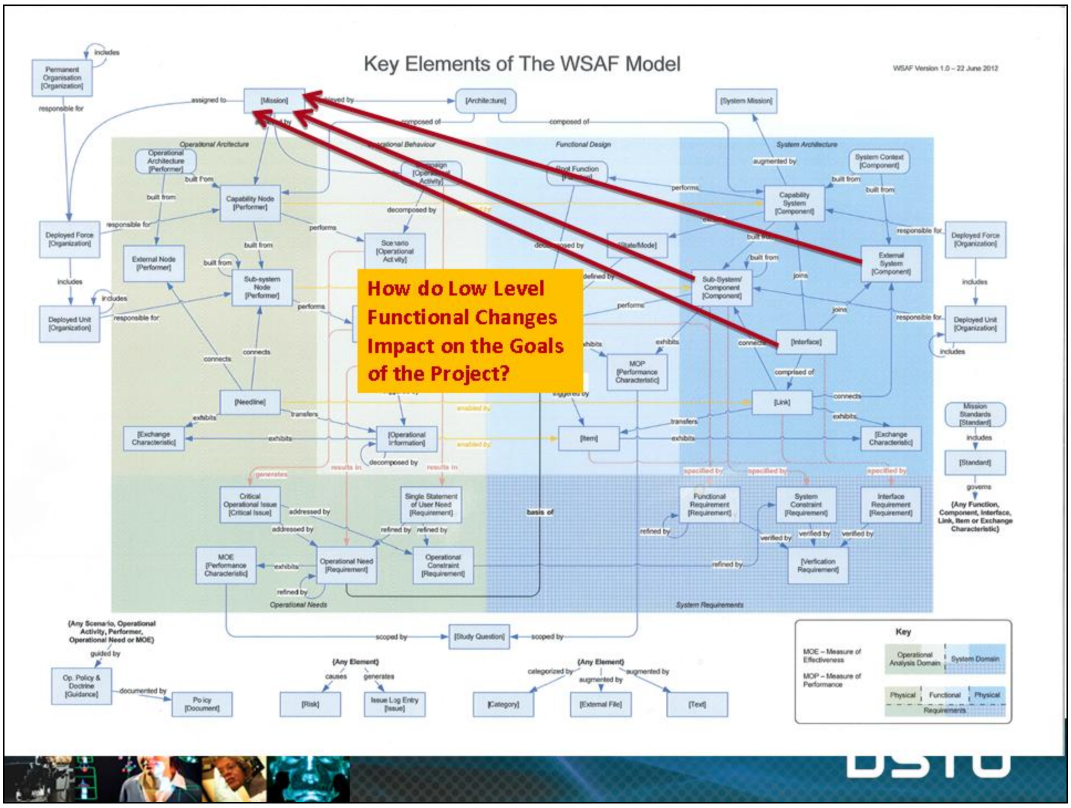
Key Elements of The WSAF Model
WSAF Version 1.0 – 22 June 2012
How do Low Level Functional Changes Impact on the Goals of the Project?

Capability Development Life Cycle - Responsibilities

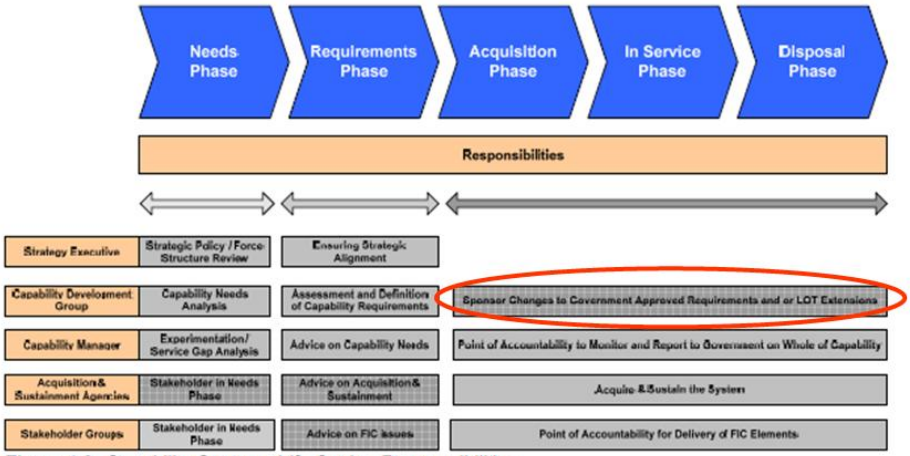

Figure 1-2: Capability Systems Life Cycle - Responsibilities

Defence Capability Development Handbook, Commonwealth of Australia, 2011

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The Challenge

Three reasons why this could get difficult

1. **Developing a tool**

2. Applied to **large complex system development**

3. Attempts to **enhance the clarity of how decisions at lower levels impact on the goals of the project.**

Risk Increasing

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Rationale for the Proposed Tool

Requirement: Quantify how low level decisions impact on the goals of the Project.

When: During acquisition phase of Capability Development Lifecycle.

Why Not Done Now: complexity, cost and delay.

DSTO advice needs to be timely, accurate and independent

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Tool Requirements

1. Fast and automated, 1 week turnaround for advice,
2. Run with a minimum of manual effort,
3. Works across the entire MBSE Project database
4. Deliver results in formats readily understood by decision makers
5. Staffing limited for tool development and application

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Approach to Enhancing the Clarity of Low Level Decisions on the Goals of Large Complex Projects

1. Project Goals measured by submarine's ability to meet Top Level Requirements.

2. Achievement of Top Level Requirements tested by submarine behaviour within agreed defined scenarios and vignettes.

3. Submarine behaviour captured by executable functional chains containing probability distributions and analytical expressions.

4. Therefore measuring whether Project Goals are being met can be tested by executing submarine functional chains within scenarios and vignettes defined by the Top Level Requirements.

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Approach Informed by Work in Other Types of Warfare

1. Mine Warfare Command Tactical Decision Aides
   Calculated effect of low level changes on MCM Task Group Operations. Used Monte Carlo simulations, analytical expressions, and probability theory.
   Must be calculated every task cycle.

2. Maritime Air Defence Combat System Performance Prediction using MBSE.
   Calculation time twelve hours once models built.

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White Paper Strategic Roles of FSM

DEFENCE WHITE PAPER 2009:
Chapter 9 p70

The Future Submarine will be capable of a range of tasks such as;

1. Anti-ship warfare;
2. Anti-submarine warfare;
3. Strategic strike;
4. Mine detection and mine-laying operations;
5. Intelligence collection;
6. Supporting special forces (including infiltration and exfiltration missions);
7. Getting battlespace data in support of operations.

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Impact of High Level Function Failure on Project Goals

Tasks	ASuW	ASW	SS	MW	Intel	BD
Sonar Passive	X	X	X	X	X	X
Sonar Active		X				
Sonar HF Active				X		
ESM	X		X		X	X
Periscope	X		X		X	X
Bathometer				X		
Radio					X	
Mk 48 ADCAP	X	X				
Harpoon	X					
Land Attack			X			

Sub. Tasks - Defence White Paper 2009

ASuW	**Anti-Ship Warfare**
ASW	**Anti-Submarine Warfare**
SS	**Strategic Strike**
MW	**Mine Warfare**
Intel	**Intelligence Collection**
BD	**Battlespace Data**

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Tool Implementation – a possible approach

1. One complete high level function failure is not likely

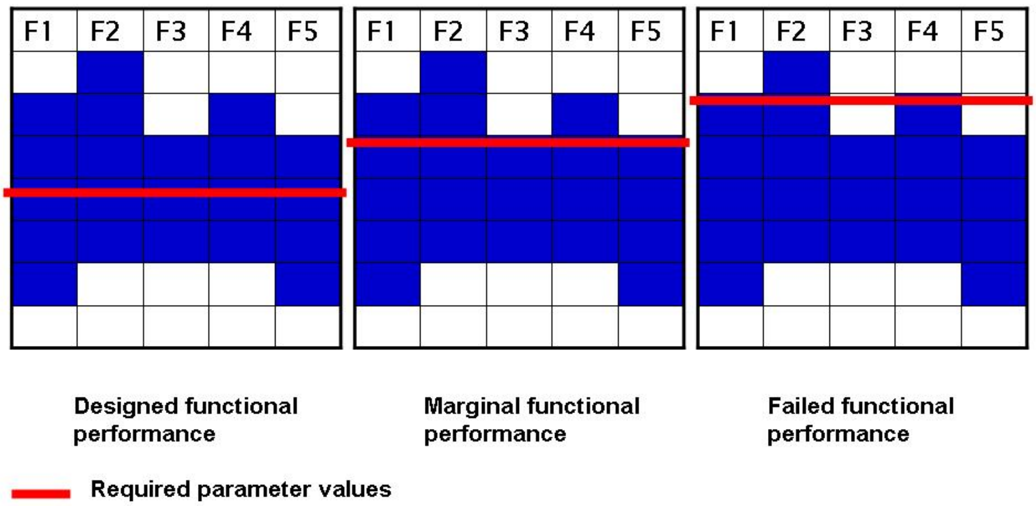
2. Reality is marginal performance changes in some functions

3. Approach for tool construction: functional chains executing scenarios and vignettes with MBSE

4. Functions incorporate external information: analytic expressions, tables, graphs, probability distributions etc.

5. MBSE Model execution tightly connected to Operational Requirements, Architecture and System Engineering database.
   - Removes translation errors between models
   - Enables cross referencing within MBSE database

Illustration of Designed, Marginal and Failed Functional Behaviour



Mine Warfare Modelling - Levels of Abstraction

Level	Type of model	Characteristics of model
Mine-target sweep interaction, MH Sonar, single asset against single mine type	Detailed physics (magnetic acoustic sweep, sonar hunt) using MC simulation	Large, detailed taking weeks to provide results as cross channel profile MoP's
Single Asset, Single Pass, multiple mine type, sweep or hunt	Calculation of single pass for a single asset against multiple mine threats MoP	Equation combining single pass cross channel MoP to multiple mine clearance cross channel MoP
Single asset, multiple pass, sweep or hunt	Calculation of multiple pass, single asset against multiple threats MoP	Complex equation transforming single pass MoP to a single asset, multiple pass MoP (Clearance plot)
Multiple Asset, multiple pass combined hunting and sweeping	Calculation of combined clearance for hunting and sweeping assets	Complex equation working from a plot combining achieved Clearance from single assets MoP to multiple assets Clearance Level (Combined Clearance MoP)
Correlate mines removed plot with Clearance plot to provide MoE for threat to transitor	Calculation of mines remaining and threat to transitor	Simple (but very clever) calculation of MoE

Calculation Done within 12 hour Tasking Cycle

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Submarine Warfare Modelling – Levels of Abstraction

Level	Type of Model	Characteristics of Model
Basic Functions: sensors, weapons, information management, platform models	Detailed physics models, Integrated Platform System Model	Large, detailed, major effort to maintain, slow to generate results (months) possibly as probability or sub-function
CS functions: Detection, TMA, Targeting, SINS POE, …	Single sub-function performance model in CORE including effects such as probability distributions and computing resources	EFFBD execution with internal calculation. A probability distribution or a sub-function model could be used in the next level.
Target engagement	CS model execution (prior example ANZAC Extant)	EFFBD execution with internal calculation. Output: probability distribution or a sub-function model could be used in the next level.
Multiple Target engagement	CS model of multiple Target engagement (prior example ANZAC ASMD)	EFFBD execution with internal calculation. Output: probability distribution or a sub-function model could be used in the next level.
Task (Described in DoDAF CORE. Application should model defined scenarios with sufficient accuracy)	Defined scenario DoDAF CORE Operational model	EFFBD execution with internal calculation: Output result in format suitable for Decision Makers i.e. Probability/Traffic Light colour

Calculation Done within One week

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Layout of the Modelling Layers Contained within 'Clarity' Tool & How it Can Support Timely Decisions

1. Detailed models from:
   The Integrated Platform System Model (MPD, DSTO) for whole of submarine margins
   Physics and engineering for sensors and weapons
   With Prior modelling calculation time - weeks

2. Executable models in MBSE (CORE).
   Use 'distilled' information from above within MBSE Functions
   Submarine functional chain execution in scenarios & vignettes
   Informed by Operations Research
   Parametric analysis (minimal) - changes in few low level functions
   Computation time - days

3. Final layout of results in formats for decision makers
   May require information display tools outside MBSE (CORE)

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Challenges for Tool Development

1. Inputting the FSM Project into MBSE
   1.1 Helpful:
   Capability Development using WSAF (MBSE CORE)
   Should have two – five years

   1.2 Difficult:
   Low level changes to functions need detailed implementation – may be difficult within Project response times

2. Moving between operations and engineering understanding of parameter values during Project?

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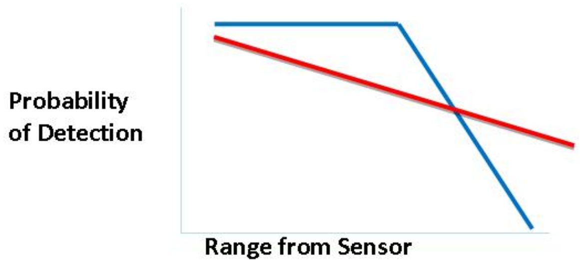
Engineering vs Operations Understanding of Parameter Values

1. Operational performance measured from operational/exercise analysis vs.

2. Engineering Performance calculated from physics and engineering signal processing



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Is it worth doing?

How else might it be done?

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